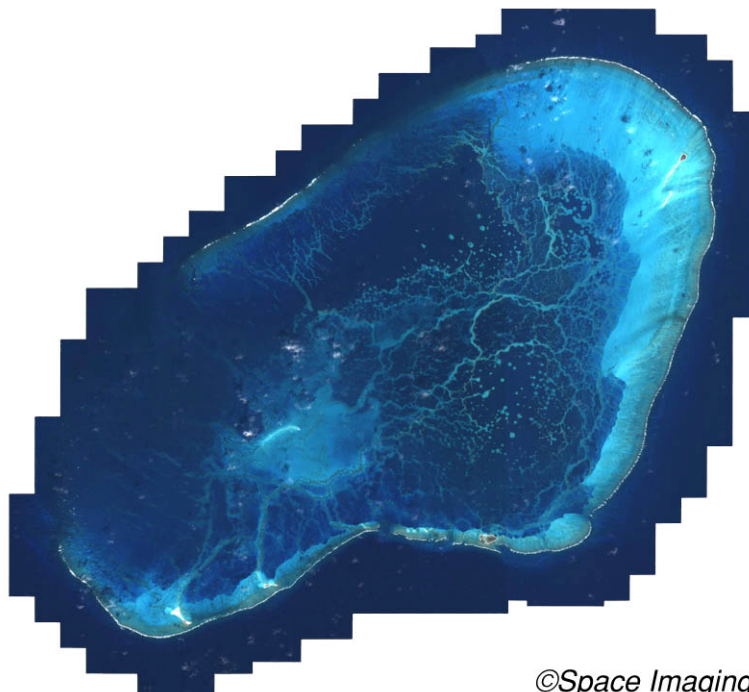


DRAFT  
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**CLASSIFICATION SCHEME FOR BENTHIC HABITATS:  
NORTHWEST HAWAIIAN ISLANDS**

**IKONOS satellite image of Pearl and Hermes Atoll**



*©Space Imaging*



**NOAA National Ocean Service  
National Centers for Coastal Ocean Science  
Center for Coastal Monitoring and Assessment  
Biogeography Program**

## INTRODUCTION

This classification scheme will be used in the applied mapping component of the overall project to produce comprehensive digital coral reef ecosystem maps for all U.S. States, Territories, and Commonwealths within five to seven years. Benthic habitat maps for the Northwest Hawaiian Islands (NWHI) will be created using computer software to analyze digital satellite imagery (IKONOS). Imagery will be classified into levels of classification that meet the needs of both the management and scientific community. Developing this classification scheme is an important step in determining the type of map products to be produced from the imagery. To facilitate development of the digital benthic habitat maps, NOAA and its partners have produced a classification manual (*Methods Used to Map the Benthic Habitats of Puerto Rico and the U.S. Virgin Islands*) that describes the specific methods used in image interpretation and habitat classification (Kendall et al. 2001). A description of the supervised image analysis procedures to be used for mapping benthic habitats of the NWHI will be forthcoming.

This draft version of the NWHI classification scheme is the result of a workshop held on 28 June 2001 in Honolulu, HI with the following intent.

**Goal:** Define discrete benthic habitats within hierarchical categories.

**Factors influencing habitat classification scheme:**

- Management needs
- Minimum mapping unit
- Spatial and spectral limitations of imagery (IKONOS)
- Consistency amongst existing classification schemes (main Hawaiian, Puerto Rico and USVI)
- Existing NWHI classification schemes

**Pending:**

- Field testing of classification scheme
- Peer review workshops

## GENERAL DESCRIPTION OF THE CLASSIFICATION SCHEME

The classification scheme defines benthic communities on the basis of two attributes: large geographic “zones” which are composed of smaller “habitats”. Zone refers only to benthic community location and habitat refers only to substrate and/or cover type. Every polygon on the benthic community map will be assigned a habitat within a zone (e.g. sand in the lagoon, or sand on the bank). Zone indicates polygon location and habitat indicates composition of each benthic community delineated. Combinations of habitat and zone that are analogous to traditionally used terminology are noted where appropriate. The description of each zone and habitat will include example images. The zone/habitat approach to the classification scheme was outlined by the Caribbean Fishery Management Council; Dr. Ken Lindeman, Environmental Defense; and the NOS Biogeography Team.

**An additional attribute has been added to the classification scheme for the NWHI that is not present in previous schemes developed for the main Hawaiian Islands and Puerto Rico and the USVI. One outcome of the initial habitat classification workshop for the NWHI was that differences in system type (atoll, bank) may influence the biological function of certain habitat types. Therefore, a system attribute will be included for each polygon.**

**Two systems were identified, atolls and banks. Banks were further subdivided into banks with carbonate islands, basalt islands or no island.**

Twelve zones were identified from land to open water corresponding to insular shelf and coral reef geomorphology typical in the NWHI (Fig. 1-2). These zones include: land, island

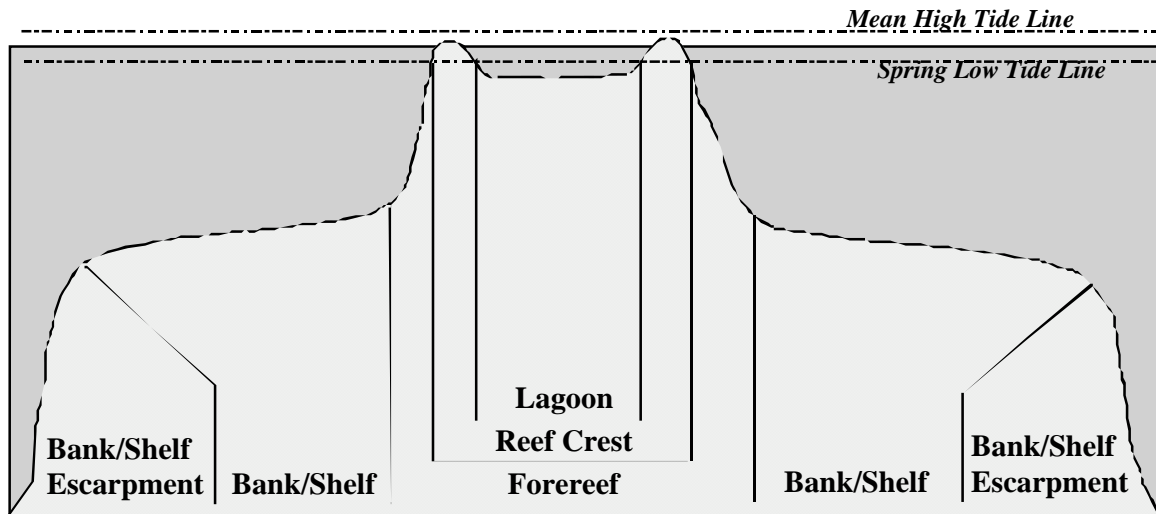
vertical wall, shoreline/intertidal, lagoon, reticulated reef, back reef, reef crest, fore reef, bank/shelf, bank/shelf escarpment, and dredged (since this condition eliminates natural geomorphology). Zone refers only to each benthic community's location and does not address substrate or cover types within. For example, the lagoon zone may include patch reefs, sand, and seagrass beds, however, these are considered structural elements that may or may not occur within the lagoon zone and therefore, are not used to define it. **A new zone, reticulated reef, was added for the NWHI which encompasses expansive areas of complex reef formations and other habitats found in the NWHI. One conclusion of the workshop was that these areas did not fit well into any other zone category and were unique enough to justify their own. The name and definition of this category are still very much open to discussion.**

Twenty-one habitat types were identified that might be mapped by psuedo-automated analysis of remotely collected satellite imagery. Habitats or features that cover areas smaller than the expected MMU (1/4 to 1/2 acre) were not considered. Habitat refers only to each benthic community's substrate and/or cover type and does not address location on the shelf. Habitats are defined in a collapsible hierarchy ranging from four broad classes (submerged vegetation, unconsolidated sediment, coral and hard bottom, and other), to more detailed categories (e.g., seagrass, algae, individual patch reefs, volcanic rock), to patchiness of some specific features (e.g., 50-90 percent cover of seagrass). **Like the new reticulated reef zone, a reticulated reef habitat was added to define those areas of complex habitat within the NWHI whose component parts are smaller than the MMU. Again, the name and definition of this category are open to discussion.**

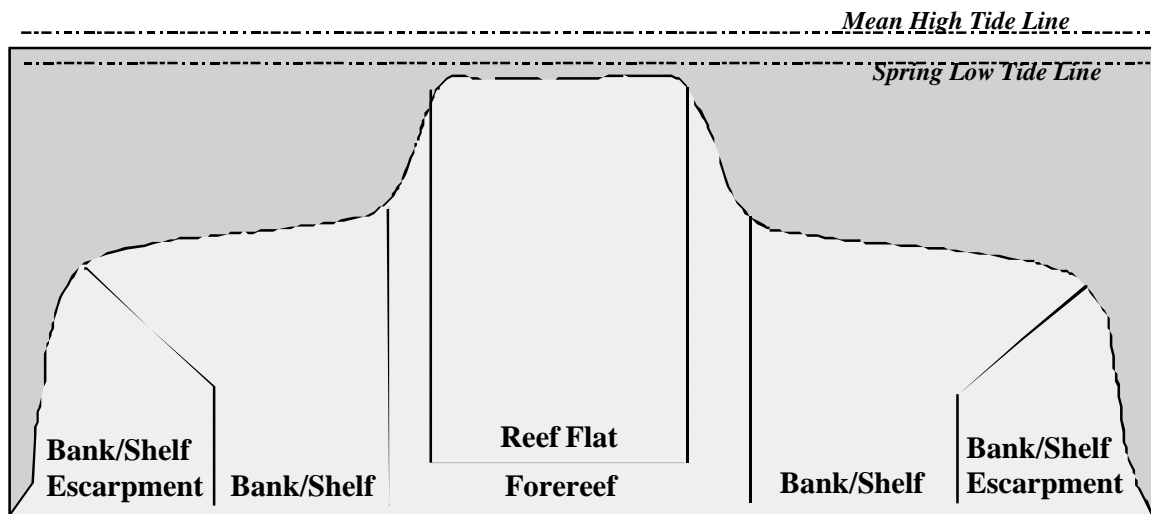
## SYSTEMS (GEOMORPHOLOGY)

### Atoll

Kure, Midway, Pearl and Hermes, French Frigate Shoals



### Bank



Banks systems are further subdivided based upon the type of island present, if any:

- a) carbonate island(s) - Laysan, Lisianski
- b) basalt island(s) - Necker, Nihoa, Gardner Pinnacles
- c) no island - Maro Reef

**One or more zones may be absent from a given system.**

## **ZONES**

**Land**

**Shoreline Intertidal**

**Vertical Wall\***

**Lagoon**

**Reticulated Reef**

**Back Reef (w/ Lagoon)**

**Reef Flat (w/o Lagoon)**

**Reef Crest**

**Fore Reef**

**Bank/Shelf**

**Bank/Shelf Escarpment**

**Channel\***

**Dredged\***

**Unknown**

\*not depicted in figures

## **HABITATS**

### **Unconsolidated Sediments (<10% vegetation or hardbottom)**

**Sand**

**Carbonate Mud**

### **Submerged Vegetation**

**Seagrass**

**Continuous Seagrass (50%-100% Cover)**

**Patchy (Discontinuous) Seagrass (10%-<50% Cover)**

**Macroalgae (fleshy and turf)**

**Continuous Macroalgae (50%-100% Cover)**

**Patchy (Discontinuous) Macroalgae (10%-<50% Cover)**

### **Corals and Hardbottom**

**Linear Reef**

**Aggregated Coral**

**Spur and Groove**

**Individual Patch Reef**

**Aggregated Patch Reef**

**Scattered Coral/Rock in Unconsolidated Sediment**

**Pavement**

**Pavement with Sand Channels**

**Volcanic Rock**

**Rubble**

**3° modifier - cover types for Corals and Hardbottom habitats:**

**Coral Colonized Hardbottom (> 10% coral cover)**

**Uncolonized Hardbottom**

**Encrusting/Coralline Algae (> 10%, but < 10% coral)**

**4° modifier - cover type modifiers:**

**with light algae**

**with dense algae**

### **Other Delineations**

**Land**

**Emergent Vegetation**

**Artificial**

**Unknown**

*Colonized generally refers to a substrate with more than 10% live cover.*

## DESCRIPTION OF ZONES AND HABITATS:

### SYSTEMS (*GEOMORPHOLOGY*)

**Atoll:** Reef surrounding a lagoon.

**Bank:** Submerged platform close enough to the surface to support a reef community.

### ZONES

**Shoreline Intertidal:** Area between the mean high water line (or landward edge of emergent vegetation when they are present) and lowest spring tide level (excluding emergent segments of barrier reefs). Typically, this zone is narrow due to the small tidal range in the Hawaiian Islands.

**Typical Habitats:** Sand, seagrass, volcanic rock and pavement and rubble.

**Vertical Wall:** Area with near-vertical decline from shore to shelf or shelf escarpment. This zone is typically narrow and may not be distinguishable in remotely gathered imagery.

**Typical Habitats:** Volcanic rock, algae, and coral.

**Lagoon:** Shallow area (relative to the deeper water of the bank/shelf) between the shoreline intertidal zone and the back reef of a reef or a barrier island. This zone is protected from the high-energy waves commonly experienced on the bank/shelf and reef crest. If no reef crest is present there is no lagoon zone.

**Typical Habitats:** Sand, seagrass, algae, pavement, volcanic/carbonate rock, and patch reefs.

**Reticulated Reef:** Area on a bank or within an atoll lagoon containing complex reef habitat with a network of sand channels, holes and other habitat types. Barrier reef and lagoon zone may or may not be present.

**Typical Habitats:** Sand, linear reef, patch reef, seagrass, and algae.

**Reef Flat:** Shallow (semi-exposed) area between the shoreline intertidal zone and the reef crest of a fringing reef. This zone is protected from the high-energy waves commonly experienced on the shelf and reef crest. Reef flat is typically not present if there is a lagoon zone.

**Typical Habitats:** Sand, reef rubble, seagrass, algae, and patch reef.

**Back Reef:** Area between the seaward edge of a lagoon floor and the landward edge of a reef crest. This zone is present when a reef crest and lagoon exists.

**Typical Habitats:** Sand, pavement and rubble, seagrass, algae, linear reef, and patch reef.

**Reef Crest:** The flattened, emergent (especially during low tides) or nearly emergent segment of a reef. This zone lies between the back reef and fore reef zones. Breaking waves will often be visible in aerial images at the seaward edge of this zone.

**Typical Habitats:** Pavement and rubble and linear reef.

**Fore Reef:** Area from the seaward edge of the reef crest that slopes into deeper water to the landward edge of the bank/shelf platform. Features not forming an emergent reef crest but still

having a seaward-facing slope that is significantly greater than the slope of the bank/shelf are also designated as fore reef (Fig. 2).

**Typical Habitats:** Linear reef and Spur and Groove.

**Bank/Shelf:** Deep water area (relative to the shallow water in a lagoon) extending offshore from the seaward edge of the fore reef to the beginning of the escarpment where the insular shelf drops off into deep, oceanic water. The bank/shelf is the flattened platform between the fore reef and deep open ocean waters or between the shoreline/intertidal zone and open ocean if no reef crest is present.

**Typical Habitats:** Sand, patch reefs, algae, seagrass, linear reef, pavement and rubble, pavement with sand channels, and other coral reef habitats.

**Shelf Escarpment:** The edge of the bank/shelf where depth increases rapidly into deep, oceanic water. This zone begins at approximately 20 to 30 meters depth, near the depth limit of features visible in aerial images. This zone extends well into depths exceeding those that can be seen on aerial photographs and is intended to capture the transition from the shelf to deep waters of the open ocean.

**Typical Habitats:** Sand, linear reef, and spur and groove.

**Dredged:** Area in which natural geomorphology is disrupted or altered by excavation or dredging.

**Typical Habitats:** Sand, mud.

**Channel:** Naturally occurring channels that often cut across several other zone types.

**Typical Habitats:** Sand, mud, uncolonized pavement.

**Unknown:** Zone uninterpretable due to turbidity, cloud cover, water depth, or other interference.

## HABITATS

**Unconsolidated Sediments:** Unconsolidated sediment with less than 10 percent cover of submerged vegetation.

**Sand:** Coarse sediment typically found in areas exposed to currents or wave energy.

**Calcareous Mud:** Fine sediment associated with buildup of organic material in areas sheltered from high-energy waves and currents.

**Submerged Vegetation:** Greater than 10 percent cover of submerged vegetation in unspecified substrate type (usually sand, mud, or hardbottom).

**Seagrass:** Habitat with 10 percent or more cover of seagrass (e.g., *Halophila sp.*).

**Continuous Seagrass:** Seagrass covering 50 to 90 percent or more of the substrate. May include blowouts of less than 10% of the total area that are too small to be mapped independently (less than the MMU). This includes continuous beds of any shoot density (may be a continuous sparse or dense bed).

**Patchy Seagrass:** Discontinuous seagrass (10 to 50 percent cover) with breaks in coverage that are too diffuse or irregular, or result in isolated patches of seagrass that are too small (less than the MMU) to be mapped as continuous seagrass.

***Representative Species:***

*Halophila sp.*

**Macroalgae:** An area with 10 percent or greater coverage of any combination of numerous species of red, green, or brown macroalgae. Usually occurs in shallow backreef and deeper waters on the bank/shelf zone.

**Continuous Macroalgae:** Macroalgae covering 50 to 90 percent or greater of the substrate. May include blowouts of less than 10 percent of the total area that are too small to be mapped independently (less than the MMU). This includes continuous beds of any density (may be a continuous sparse or dense bed).

**Patchy Macroalgae:** Discontinuous macroalgae (10 to 50 percent cover) with breaks in coverage that are too diffuse or irregular, or result in isolated patches of macroalgae that are too small (smaller than the MMU) to be mapped as continuous macroalgae.

***Representative Species:***

*Dictyosphaeria spp.*

*Halimeda spp.*

**Corals and Hardbottom:** Hardened substrate of unspecified relief formed by the deposition of calcium carbonate by reef building corals and other organisms (relict or ongoing) or existing as exposed bedrock or volcanic rock.

**Corals and Colonized Hardbottom:** Substrates formed by the deposition of calcium carbonate by reef building corals and other organisms. Habitats within this category have some colonization by live coral, unlike the uncolonized hardbottom category.

**Representative Species/Live Coral Community:**

*Porites compressa*

*Porites lobata*

*Montipora* spp.

*Pocillopora meandrina*

**Uncolonized Hardbottom:** Hard substrate composed of relict deposits of calcium carbonate or exposed volcanic rock.

**Encrusting/Coralline Algae:** An area with 10 percent or greater coverage of any combination of numerous species of encrusting or coralline algae. May occur in shallow backreef, relatively shallow waters on the shelf zone, and at depth.

***Representative Species:***

*Porolithon gardineri*

**Continuous Encrusting/Coralline Algae:** Encrusting/coralline algae covering 50 to 90 percent of the substrate.

**Patchy (Discontinuous) Encrusting/Coralline Algae:** Discontinuous encrusting/coralline algae (10 to 50 percent cover) with breaks in coverage that are too diffuse or irregular, or result in isolated patches of coralline algae that are too small (less than the MMU) to be mapped as continuous coralline algae.

**Linear Reef:** Linear coral formations that are oriented parallel to shore or the shelf edge. These features follow the contours of the shore/shelf edge. This category is used for such commonly used terms as fore reef, fringing reef, and shelf edge reef.

**Aggregated Coral:**

**Spur and Groove:** Habitat having alternating sand and coral formations that are oriented perpendicular to the shore or bank/shelf escarpment. The coral formations (spurs) of this feature typically have a high vertical relief relative to pavement with sand channels (see below) and are separated from each other by 1-5 meters of sand or bare hardbottom (grooves), although the height and width of these elements may vary considerably. This habitat type typically occurs in the fore reef or bank/shelf escarpment zone.

**Patch Reef(s):** Coral formations that are isolated from other coral reef formations by sand, seagrass, or other habitats and that have no organized structural axis relative to the contours of the shore or shelf edge.

**Individual patch reef:** Distinctive single patch reefs that are larger than or equal to the MMU.

**Aggregate patch reefs:** Clustered patch reefs that individually are too small (less than the MMU) or are too close together to map separately.

**Scattered Coral/Rock in Unconsolidated Sediment:**

**Pavement:** Flat, low-relief, solid or rubble carbonate rock with coverage of macroalgae, hard coral, zoanthids, and other sessile invertebrates that are dense enough to begin to obscure the underlying surface.

**Pavement with Sand Channels:** Habitat having alternating sand and colonized pavement formations that are oriented perpendicular to the shore or bank/shelf escarpment. The sandchannels of this feature have low vertical relief relative to spur

and groove formations. This habitat type occurs in areas exposed to moderate wave surge such as the bank/shelf zone.

**Volcanic Rock:** Solid volcanic rock that has coverage of macroalgae, hard coral, zoanthids, and other sessile invertebrates that begins to obscure the underlying surface.

**Rubble:** Dead, unstable coral rubble often colonized with filamentous or other macroalgae. This habitat often occurs landward of well developed reef formations in the reef crest or back reef zone.

#### **Other Delineations:**

##### **Land:**

**Emergent Vegetation:** Emergent habitat composed primarily of ??? *Rhizophora* mangle (red mangrove) and hao trees ???. Generally found in areas sheltered from high-energy waves. This habitat type is usually found in the shoreline/intertidal, back reef, or barrier reef crest zone.

**Artificial:** Man-made habitats such as dredged channels, large piers, submerged wrecks, submerged portions of rip-rap jetties, and the shoreline of islands created from dredge spoil. Includes active and remnant fish ponds walled off from the open ocean along the shoreline, often along a reef crest.

**Unknown:** Bottom type unknown due to turbidity, cloud cover, water depth, or other interference.

## WORKSHOP PARTICIPANTS

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## CHANGES

- 3/14/02 Removed individual and aggregated coral heads to bring scheme in line with main eight scheme. This habitat type is now covered by Scattered Coral/Rock in Unconsolidated Sediment.
- 3/14/02 swapped structure and cover type in the hierarchy for Coral Reef and Hardbottom habitats so that structure comes first. Cover type modifies structure and can be further modified by algal cover.
- 7/16/01 removed "calcareous" from the term pavement as it is implicit in the description.
- 7/16/01 colonized/uncolonized order was swapped for corals and hardbottoms to bring it in line with main 8 and Caribbean classification schemes. Specifically colonized/uncolonized designation was switched from 2<sup>nd</sup> to 3<sup>rd</sup> level within the habitats.
- 7/16/01 removed Vertical Wall as a habitat. Discussions during the workshop suggested that Vertical Wall describes a zone. Various habitats may exist within that zone.
- 7/16/01 removed Reticulated Reef as a habitat. Intent during the workshop was to treat Reticulated Reef as only a zone. Other habitats may be identified within that zone.
- 7/16/01 removed third level habitats from within Artificial habitat, primarily to save space. These designations are explicitly stated in the description and require field data to verify, so are not really needed in the outline.
- 12/6/01 Added Channel as zone as per discussions with Miles and for consistency with the Main Hawaiian scheme.
- 12/6/01 Added Reef Rubble habitat as there is some discussion that that 10-50% reef rubble in sand will be distinguishable from other habitats. Rubble was separated from Uncolonized Pavement as per the Main Hawaiian scheme.